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DESCRIPTION OF THE SKULL AND SEPARATE CRANIAL BONES OF THE WOLF-EEL (*ANARRHICHTHYS OCELLATUS*).

BY L. A. ADAMS.

(Contribution from the Zoölogical Laboratory, No. 183.)
Submitted in partial fulfilment of the requirements for the degree of Master of Arts.

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THE skull here described is that of *Anarrhichthys ocellatus*, or wolf-eel. The *Anarrhichadidæ* proper are found in the northern waters, few coming farther south than the fiftieth parallel, and indeed most of them are found within the Arctic circle. The subfamily *Anarrhichthys* is found farther south, and the species described was taken at Monterey Bay, California.

The description from Jordan and Evermann's "Fishes of North and Middle America" is as follows:

"Family *Anarrhichadidæ*, p. 2445, vol. III.

"Body oblong or elongate, covered with rudimentary scales; no lateral line. Head scaleless, without cirri, its bones very thick and strong, the profile strongly decurved. Mouth very large, oblique, the jaws anteriorly with very strong conical canines; sides of lower jaw with very strong molar teeth, which shut against a series of very coarse molars on the palatines; vomer solid, armed with very strong molar teeth, the dentition adapted for crushing sea-urchins and mollusks. Gill membranes broadly united to the isthmus; no pyloric cæca. Dorsal fin high, composed entirely of flexible spines; no ventral fins; pectoral fins broad, placed low. Large carnivorous fish of the northern seas. Two genera and about six species known."

(Blennidæ, pt., Günther, Cat. iii, 208-211, 1861.)

The species *Anarrhichthys ocellatus* is found along the Pacific coast in the bays and inlets. These fish live on sea-urchins and sand-dollars, for which food their dentition is well adapted. They are very vicious, and when taken into a boat will snap their jaws very much like a dog or wolf, so they are well named wolf-fish. They are eel-shaped, and are sometimes called wolf-eels. The following is the description of this fish in Jordan and Evermann (*Anarrhichthys ocellatus* Ayres, wolf-eel):

"Head 11, depth 15 D.CCL; A. 233; P. 19. Body elongate, formed as in an eel; the head and jaws very strong. Pectorals broad, more than one-half head; longest spine, dorsal, one-half head. Color dark greenish, the body and dorsal fin everywhere covered with round, ocellated black spots of various sizes, the light markings forming reticulations around the spots; head paler, with reticulations of a finer pattern; anal pale edged. Length, 5 to 8 feet. Pacific coast, from Monterey Bay north to Puget Sound. It feeds chiefly on sea-urchins and sand-dollars. (Ocellatus, with eye-like spots.)"

(*Anarrhichthys ocellatus* Ayres, Proc. Cal. Ac. Nat. Sci., 1855, 31, San Francisco; Jordan and Gilbert, Synopsis, 1893, 782; Jordan and Starkes, Fishes Puget Sound, 1895, 848.)

GENERAL DESCRIPTION OF THE SKULL.

A side view of the skull is shown in plate XXV, figure 1. From this some idea may be obtained of the great strength of the jaws, with their dentition. The front part of the jaws is

armed with large canine-like teeth, conical in shape; farther back, on the vomer and palatines, are the large, rough molars or grinding teeth. The posterior part of the mandible is also armed with large teeth.

The length of the skull is very little greater than the depth; the width is slightly less than the length.

The skull is laterally compressed and very thin on the posterior part of the dorsal edge. Both the frontal and the parasphenoid are drawn out into knife-like edges on the posterior part of the dorsal and ventral portion of the bones. The following bones are noted from this view:

1. Supraoccipital.	6. Alisphenoid.	11. Parasphenoid.
2. Exoccipital.	7. Sphenotic.	12. Frontal.
3. Basioccipital.	8. Pterotic.	13. Ethmoid.
4. Epiotic.	9. Parietal.	14. Prefrontal.
5. Prootic.	10. Opisthotic.	15. Vomer.

The occipital region of the skull is very interesting in its structure, and has a peculiar arrangement of the bones, a great deal like some of the fossil forms of the Cretaceous. This may be seen in plate XXVIII, figure 4. The supraoccipital is placed in between the parietals, and the epiotics are immediately below it, forming a part of the foramen magnum. Ventral to the epiotics are the exoccipitals, the opisthotics extending posteriorly from them.

Teeth.

The teeth are remarkable for fish teeth, and are the most striking thing noticed in this fish. They are of two kinds, the canine-shaped and the heavy molar type. The conical teeth are long and pointed and the grinders are rough and very heavy.

Teeth are found on the following bones: Premaxillæ, vomers, palatines and dentaries; the maxillæ bearing no teeth. The number of teeth is not constant and varies greatly in different specimens. In three specimens they occur as follows: Premaxilla, 8-9; vomer, 9-10; palatine, 5-7; dentary, 11-16; the total number in these three skulls being 66-86. The largest teeth are on the vomer. They are rounded and very heavy and furnish much of the grinding surface.

The palatines are found on each side of the vomer and are well supplied with teeth. The teeth on the mandibles are so placed that they work against those of the palatines and vomer, the mandible being inclined inward. Most of the teeth on the

premaxillæ are canine in form, those at the posterior being small and rounded. There are six to eight of the sharp teeth on the mandibles and about the same number on the two premaxillæ. The teeth are not placed in sockets, but, on the contrary, are hollow and are placed on cones. These cones are ridged in a neat pattern, and the base of the tooth corresponds to it, helping to hold the tooth firm.

The canine-shaped teeth are the most firmly anchored, as they would have the most strain on them. They are hollow for about one-fourth of their length and the cone is correspondingly lengthened. The heavy molars are only slightly concave at the base, but to offset this the cone is very deeply ridged and thus holds the tooth firm. Even after maceration most of them will be found in position.

Minute Structure. (See plate XXVIII, figs. 7, 8.)

The structure is quite complex for a fish tooth, there being thin layers of enamel and dentine. A longisection (see plate XXIX, fig. 9) shows many canals radiating toward the periphery. The canals start from a cavity at the apex of the concavity of the base, and all extend upwards and outwards toward the periphery, where they branch out, forming a network under the enamel. A transverse section (plate XXIX, fig. 10) shows the canals in cross-section, and also a longisection of some of them where they are curving outward to the periphery. The teeth do not show any striations under the lens, but are smooth and polished on the sides, the upper portion being roughened by use. The sides are ridged near the base and correspond to the outline of the cone on which they are placed. The pattern of the cone is so marked that it is easy to replace the teeth on the right cones, even after they are removed and misplaced. (See plate XXVIII, fig. 8.)

DETAILED DESCRIPTION OF THE INDIVIDUAL BONES OF THE SKULL.

The skull is made up of the following bones and they are described in this order:

1. Supraoccipital.
2. Exoccipital.
3. Basioccipital.
4. Epiotic.
5. Prootic.
6. Opisthotic.
7. Parietal.
8. Pterotic.
9. Sphenotic.
10. Alisphenoid.
11. Parasphenoid.
12. Frontal.
13. Prefrontal.
14. Ethmoid.
15. Vomer.
16. Suborbitals.
17. Hyomandibular.
18. Metapterygoid.

19. Symplectic.	23. Palatine.	27. Dentary.
20. Quadrate.	24. Maxilla.	28. Articulare.
21. Mesopterygoid.	25. Premaxilla.	29. Angulare.
22. Pterygoid.	26. Mandible.	30. Preopercular.

SUPRAOCCIPITAL. (Plate XXVIII, fig. 4; plate XXX, figs. 16, 17, 18, 19.)

The supraoccipital is wedged in between the parietals. It is roughly a triangular inverted pyramid, with the base forming the superior posterior part of the skull. The superior angle of this bone is drawn out into a slight crest, fitting between the parietals.

Posterior Face. (Plate XXX, fig. 16.)

The base of the pyramid is triangular in outline and quite deeply concave. The two lateral edges are drawn out thin and fit against the inner face of the parietals. At the lower part of the face there is a forficate process, which overlaps and articulates with the epiotics.

Ventral Face. (Plate XXX, fig. 19.)

The ventral portion of the pyramid forms the posterior half of the roof of the brain-cavity. This is narrowed down anteriorly, a thin tongue fitting in between the sphenotics. It is straight antero-posteriorly, but the sides are drawn down at an angle. A slight ridge extends along the bone longitudinally. This face is double, a thin disc being raised upon it, attached in the center, the edges free, forming a surface for the brain-cavity. This surface is not smooth, but is marked by longitudinal ridges, pits and cavities. (See plate XXX, fig. 19.)

Lateral Face. (Plate XXX, fig. 17.)

The lateral faces are triangular in outline. They are in two planes, the posterior inclining outward and backward, the other outward and downward. They articulate with the inner face of the parietal.

Articulations.

The supraoccipital has four articulations: Its anterior edge with the posterior edge of frontal, this edge fitting into a groove on the posterior edge of frontal. Laterally it articulates with the pterotics, the parietals and the inferior posterior portion of the epiotics.

Exoccipital. (Plate XXXI, figs. 32, 33, 34.)

The exoccipitals are paired bones in the caudal region of the skull, but also have a place in the sides. The lateral face of the bone is hexagonal, with the longest side placed caudally. Posteriorly it is hour-glass shaped, irregular and narrowed in the middle from the inner side, and the lower edge is cut off transversely at the expense of the inner edge. It forms about five-sixths of the boundary of the foramen magnum.

Outer Face. (Plate XXXI, fig. 32.)

The outer face is hexagonal, though far from regular. It is slightly concave, and is marked by a foramen placed almost in the middle of it which extends obliquely through the bone. From this foramen a groove passes posteriorly, bisecting the caudal border. The edges of the outer face are very irregular, being drawn out into numerous points.

Inner Face. (Plate XXXI, fig. 34.)

The inner face is irregular, the lower posterior part articulating with the cervical vertebræ. It points downward and inward. The middle of the inner face is marked by two foramina, one extending obliquely through it to the middle of the outer face; the second is posterior to it. The openings to these foramina are in a depression. On the superior posterior portion of the face there is another protuberance, which is pointed posteriorly, starting at about the middle of the inner face and articulating with the epiotic.

Articulations.

The exoccipital has six articulations: Ventrally with the basioccipital; anteriorly with the basioccipital and the prootic; superiorly with the pterotic and epiotic and with the other exoccipital.

Basioccipital. (Plate XXX, figs. 20, 21, 22, 23.)

The basioccipital is a very irregular bone. It has five faces to consider.

Posterior Face. (Plate XXX, fig. 20.)

The posterior face of the basioccipital is concave and is marked by a number of concentric rings. Slightly above the center of the concavity there is a small pit. This part of the bone articulates with the neck vertebræ. The longest axis extends dorso-ventrally.

Lateral Face. (Plate XXX, fig. 22.)

The lateral faces are rather smooth, but are depressed at the posterior edge, this edge being drawn out laterally to enlarge the posterior face.

Dorsal Face. (Plate XXX, fig. 21.)

The upper or dorsal face forms the postero-ventral part of the brain-case. It is set up above the rest of the bone, as are all of the bones forming a part of the brain-case. It is marked by numerous pits and cavities.

Anterior Face. (Plate XXX, fig. 21.)

The anterior part of the basioccipital is marked by a deep groove. It inclines ventrally and posteriorly at the expense of the ventral face. The lower part of the groove has a thin tongue of bone extending about half way to the dorsal edge. This groove articulates with the parasphenoid.

Articulations.

The basioccipital has six articulations: With the parasphenoid, prootics, exoccipitals and the first cervical vertebra. It articulates with the parasphenoid by the groove in the anterior face, with the prootics and exoccipitals by the edges, and the posterior face with the cervical vertebra.

EPIOTIC. (Plate XXXI, figs. 29, 30, 31; plate XXVIII, fig. 4.)

The epiotics are paired bones in the posterior part of the skull. They are placed ventral to the supraoccipital, against the pterotics, their anterior face forming a part of the brain-cavity. They are twice as long as wide, the long axis of the bone being placed transversely across the occipital region of the skull. The epiotics have three faces to consider.

Inner Face. (Plate XXXI, fig. 29.)

The inner face is roughly square in outline and the part of the bone forming the brain-case is covered with a thin plate of bone, as usual. This disc is pitted and is generally concave. The face articulating with the pterotics is concave and is marked with numerous ridges which fit into corresponding grooves on the pterotic.

Outer Face. (Plate XXXI, fig. 30.)

The outer face is concave on the short axis and is roughly rectangular in shape, the outer end being narrowed down to a rounded projection. The face articulating with the pterotic is at right angles to that forming a part of the brain-case.

Articulations.

The epiotic has six articulations. The two epiotics do not meet on the median line. In the dry skull they seem to have been united by a cartilage. They articulate with the supraoccipital on the dorsal edge, a thin tongue of bone from the supraoccipital overlapping its dorsal inner edge. They articulate with the pterotics anteriorly, the surfaces being roughened by ridges and grooves. The ventral and exterior edges articulate with the opisthotic and the exoccipital. The ventral edges of the epiotics form the dorsal border of the foramen magnum.

PROOTIC. (Plate XXIX, fig. 11; plate XXX, figs. 12, 13, 14.)

The prootics are ventral to the sphenotics, posterior to the parasphenoid and superior to the basioccipital and parasphenoid, the latter extending posteriorly under it. In shape it is roughly pentagonal but is very irregular in outline, the ventral edge being marked by many serrations.

Outer Face. (Plate XXX, fig. 14.)

The outer face is marked by a long, irregular ridge, extending from the posterior superior portion, where it is quite prominent, down to the antero-ventral edge. At the middle of this ridge is a large foramen, extending through the bone and coming out at the superior edge. This foramen is for a part of the fifth nerve. On the superior anterior part of the bone is another protuberance, which aids in forming the pit for the hyomandibular head.

Inner Face. (Plate XXX, fig. 12.)

The inner face also is quite irregular. It forms the lower posterior side of the brain-case. On the lower edge of the face is a prominent slit with projecting lips, starting at the middle of the anterior border and curving posteriorly and ventrally. At the posterior edge it opens into a cavity in the bone. The foramen for the part of the fifth nerve may be seen on the ventral edge. When the bones are in position the two slits are in juxtaposition, forming a cavity through one bone and into the other at the ventral part of the brain-cavity.

Articulations.

The prootic has five articulations: Anteriorly with the parasphenoid and sphenotic, ventrally with the parasphenoid, posteriorly with the basioccipital, exoccipital and pterotic. The two prootics touch each other on the median line.

OPISTHOTIC. (Plate XXVI, fig. 2; plate XXX, fig. 15.)

The opisthotics are small bones, rectangular in shape, very thin and with two faces. They lie on the outer faces of the exoccipitals, which have slight depressions to receive them. The superior edges fit into grooves in the ventral part of the pterotic. They extend posteriorly from the exoccipitals.

PARIETAL. (Plate XXVI, fig. 2; plate XXVII, fig. 3; plate XXXIII, figs. 49, 50, 51, 52.)

The parietals and the pterotics are united in this skull, the suture being entirely obliterated and showing only as a ridge on the exterior face of the bone. The shape of the parietal, considering it separately, is a little irregular.

Outer Face. (Plate XXXIII, fig. 49.)

The outer face is concave and smooth, with the exception of the ridge marking the division line between pterotic and parietal.

Articulations.

The parietal has four articulations (considering it as a separate bone). It articulates with the supraoccipital and frontal on the inner face, its anterior edge being fitted in between the sphenotic and frontal; the ventral edge is joined to the pterotic.

PTEROTIC. (Plate XXVI, fig. 2; plate XXIX, fig. 11; plate XXXIII, figs. 49, 50, 51, 52.)

The pterotic is marked by a groove along the ventral part to contain the articulating portion of the hyomandibular. Its shape is triangular.

Inner Face. (Plate XXXIII, fig. 50.)

The inner face of the pterotic and parietal is divided, the pterotic, or ventral half, forming a part of the brain-case, and the dorsal half only an articulating surface.

Outer Face. (Plate XXXIII, fig. 49.)

The outer face is concave, smooth, and triangular in shape, with the base ventral. The parietal is placed on the anterior superior edge.

Anterior Face. (Plate XXXIII, fig. 51.)

The anterior face is at right angles to the outer face and has a long ridge extending along its surface, forming a groove for the hyomandibular. This face is roughly rectangular in shape.

A small groove for the opisthotic is seen close to the inner edge of the face.

Articulations.

Considering it separately, the pterotic has seven articulations. It articulates with the parietal dorsally; anteriorly with the sphenotic and epiotic on its inner posterior face; ventrally with the exoccipital, prootic and hyomandibular.

SPHENOTIC. (Plates XXV, XXVI, XXVII; Sph. Plate XXXIII, figs. 46, 47, 48; plate XXIX, fig. 11.)

The sphenotic extends out farther laterally than any other bone in the skull. It is posterior to the frontal and alisphenoid and extends outward and backward. It is hexagonal in shape. The posterior edge is parallel to the long axis of the skull and its posterior edge is at right angles to the long axis, and its lower edge extends anteriorly and superiorly, narrowing down to a blunt point. It has three faces, an outer, inner and posterior.

Outer Face. (Plate XXXIII, fig. 46.)

The outer face is smooth, concave from the posterior to the anterior edge and convex from the superior to the inferior edge. The posterior part is almost at right angles to the anterior, as the bone inclines outward, thus making the posterior face. The posterior edge is drawn out into a sharp ridge, making the posterior face a long groove, wide at the inferior part and narrowing rapidly at the superior portion. The lower part points downward and backward and forms the greater part of the pit for the hyomandibular, the prootic forming the rest of the cavity.

Inner Face. (Plate XXIX, fig. 11; plate XXXIII, fig. 48.)

The inner face forms a part of the brain-case and is about three times as long as wide, and is narrowed down to the anterior end and rounded posteriorly. There is a tongue on the middle of the ventral edge which fits into a groove on the prootic. This face is slightly concave, and is built up above the rest of the bone. It has a prominent depression at the posterior part. All of the bone forming a part of the brain-case is pitted and honeycombed.

Articulations.

The sphenotic has six articulations. Anteriorly it fits into a notch on the posterior part of the frontal; the antero-ventral

edge with the alisphenoid and parasphenoid; its ventral edge with the prootic, parasphenoid and hyomandibular; posteriorly with the pterotic; dorsally with the parietal and frontal.

ALISPHENOID. (Plate XXVI, fig. 2; plate XXIX, fig. 11; plate XXXIII, fig. 45.)

The alisphenoid is a thin bone, placed at the angle where the parasphenoid and frontal separate posteriorly. It is triangular in shape, with the base of the triangle placed dorsally. It is less than 2 mm. in thickness, and is merely a disc of bone. It has three articulations: Anteriorly with the parasphenoid and frontal, these overlapping its outer face so that only about one-third shows on the outside of the skull, superiorly with frontal, ventrally with parasphenoid, and posteriorly with sphenotic.

PARASPHENOID. (Plate XXVI, fig. 2; plate XXXII, figs. 40, 41.)

The parasphenoid is the second largest bone in the skull, the frontal being the largest. Its shape is irregular.

Ventral Edge.

The ventral edge is knife-like, forming a sharp keel at the posterior part. Anterior to this keel the bone widens out into a shallow trough or groove with thin edges, making a ventral face for the articulation of the vomer. The bottom of this groove is rough and has in it a smaller groove extending along the whole length of the articulating surface and fitting a tongue-like projection on the vomer. At the posterior end the parasphenoid widens out abruptly and then rapidly narrows, making a beveled surface, over which the basioccipital fits. There is a deep, narrow groove in the posterior superior border of the median line, and a thin tongue from the basisphenoid fits into it.

Dorsal Edge. (Plate XXXII, fig. 41.)

The dorsal edge is more irregular than the ventral. It expands and extends dorsally and outward. About one-third of the dorsal edge is raised in this way. It starts to expand immediately anterior to the articulation of the basioccipital, and ends anteriorly where the upper edge dips down ventrally. These expanded, up-growing wings are cut by a deep slit, reaching almost to the floor of the groove between them. The narrow part, posterior to this, articulates with the sphenotic, and the part anterior with the alisphenoid and frontal. An-

terior to the articulation with the frontal, the expanded edge drops rapidly and forms an acute projection on each side, extending toward the front; anterior to these the edge continues regular. This anterior part of the parasphenoid extends forward as a projection. The upper part is marked by a thin ridge extending along the median line. This projected anterior end of the parasphenoid flares out inferiorly, the part articulating with the vomer being wider than the upper surface. The groove between the upper edges of the parasphenoid is quite deep and narrow.

Faces.

The faces of the parasphenoid are rather smooth but marked by fine striations. At the posterior part of the expanded upper edge there is a sharp ridge, pointing posteriorly, and extending to the ventral edge; immediately posterior to the ridge, on the superior edge, there is a foramen of some size, extending into the bone anteriorly.

Articulations.

The parasphenoid has eight articulations. The anterior part articulates ventrally with the vomer, laterally with the prefrontals and anteriorly with the ethmoid. On the rest of the dorsal edge it articulates with the following, in order: frontal, alisphenoid, sphenotic, prootic and basioccipital.

FRONTAL. (Plate XXV, fig. 1; plate XXVI, fig. 2; plate XXVII, fig. 3; plate XXIX; plate XXXI, fig. 35; plate XXXII, fig. 36.)

The frontal is unpaired, and is the largest bone in the skull. Its superior edge is drawn out at the posterior part into a thin crest. Anteriorly it widens out laterally. The ventral surface has two wings articulating with the corresponding upward growth on the parasphenoid. The frontal has three faces, a postero-lateral, a dorsal, and the anterior beveled faces.

Lateral Face. (Plate XXXI, fig. 35.)

The lateral face is at the posterior half of the bone. From the thin dorsal edge it is inclined outward and posteriorly, articulating with the sphenotic. A rounded ridge extends up from this articulation to the anterior edge of the face, where it fades out. This face is marked with striations.

Dorsal Face. (Plate XXVII, fig. 3; frontal.)

The edges are gently concave, the face narrowing at the anterior end. A ridge extends along the median line of

the face, and between this ridge and the edge the face is depressed. Starting at the anterior edge of the face are two large cavities which extend posteriorly. The whole face is honeycombed, the pits extending in regular lines. The anterior end of the bone is forficate, and the articulation with the ethmoid is formed in this way, the posterior part of the ethmoid being wedge-shaped and fitting into this cavity.

Lateral Face (anterior). (Plate XXXI, fig. 35.)

The anterior lateral face is formed by the anterior end being beveled toward the ventral edge. This face is concave both ways and at the posterior end turns out laterally. There are two cavities at the postero-ventral part of each face, extending posteriorly into the bone. Just posterior to this face there is a depression for the articulation of the suborbital ring; at the center of this depression there is a foramen, extending posteriorly also. The ventral end of the frontal is hollow and sheaths the ethmoid in this cavity.

Articulations.

The frontal has eight articulations: Posteriorly with the parietal, by overlapping it; with the supraoccipital by a sharp groove in the posterior end; with the sphenotic by this bone overlapping the frontal; ventrally with the alisphenoid, which lies against the ventral wing on the inside; with the parasphenoid by the drawn-out ventral edge; with the suborbitals at the posterior part of the enlarged anterior end of the frontal; with the ethmoid anteriorly, and with the prefrontals at the anterior end of the lateral faces.

PREFRONTAL. (Plates XXV, XXVI, XXVII; plate XXXII, figs. 37, 38, 39.)

The prefrontals are irregular bones lying on each side of the ethmoid. The posterior face is concave and points posteriorly and dorsally. This face is smooth and has a large process, springing from the ventral inner portion, which articulates with the ethmoid, parasphenoid and the other prefrontal. There are two depressions in the outer edge, immediately ventral to the smooth dorsal face, which articulates with the suborbital ring; one depression or notch is cut out at the expense of the upper edge, and the posterior notch at the expense of the lower.

The inner ventral edge drops ventrally and forms a large process for articulation on the ventral and inner face. This process is very irregular. At the anterior part there is a

small, raised tubercle, which has a small facet for the articulation with palatine.

Articulations.

The prefrontal articulates with the ethmoid by two articulations, making a large foramen between the two. It articulates with the other prefrontal on the median line. The inner face is very irregular. The outer edge of the dorsal part articulates with the suborbital ring. Posteriorly it articulates with the pterygoid, and on the inner ventral edge it has a slight articulation with the vomer. The palatine fits on a slight tubercle which has a small facet; this is on the ventral part. The dorsal part of the prefrontal forms the anterior part of the orbit.

ETHMOID. (Plate XXV, Eth. plate XXVI, plate XXVII, Eth. plate XXXIII, figs. 42, 43, 44.)

The ethmoid is wedge-shaped, with the antero-ventral part drawn down ventrally. It articulates with the frontal by fitting into a cavity in the anterior end.

Anterior Face. (Plate XXXIII, fig. 44.)

The face is divided by a sharp ridge extending dorso-ventrally through its median line, making two concave surfaces, one on each side, which articulate with the premaxillæ. The lateral edges are drawn out laterally, forming two small wings, their ventral edge being a little below the center of the bone. Below these wings this face slopes rapidly posteriorly. A dorsal view of the ethmoid shows a kite-shaped outline. The dorsal surface is rather flat anteriorly for about one-third of its length, where it becomes sharp and keeled on the dorsal edge. The whole bone is compressed laterally, the dorsal edge having a prominent keel occupying its middle third.

Posterior.

A posterior view shows the upper part to be rather cone-shaped—a cone rounded at the ventral edge and sharp on the dorsal edge. At the ventral anterior part it has two articulating surfaces.

Articulations.

The ethmoid has five: Anteriorly with the two premaxillæ; posteriorly with the frontal, by the cone-shaped part being sheathed in this bone; on the postero-ventral face with the two prefrontals and parasphenoid; ventrally with the vomer.

VOMER. (Plate XXVI; plate XXX, fig. 24.)

The vomer is a large, stout bone, and is one of the strongest in the skull. It is boat-shaped, with the prow pointed posteriorly.

Lateral Faces. (Plate XXVI.)

The lateral faces are convex both ways and are wider anteriorly than posteriorly. The postero-superior edge is drawn out laterally and dorsally, making an articulation for the ethmoid and the prefrontals. There is a small tubercle on the anterior part near the dorsal edge, the articulation for the long, slender maxilla. The dorsal posterior half of the face is narrowed down, the parasphenoid fitting over it. These lateral faces are marked by several pits. There is a prominent foramen posterior to the articulation with the prefrontal, and several along the ventral edge, just above the teeth.

Ventral Face. (Plate XXX, fig. 24.)

The ventral face is the tooth-bearing surface and has nine to eleven teeth.

Dorsal Face.

The dorsal face is very irregular, and is covered with pits and cavities, large and small. A thin tongue of bone extends along the median line longitudinally, fitting into a groove in the parasphenoid. The anterior half of this face is raised and extended out laterally, having a dentate edge which articulates with the prefrontals and the ethmoid.

Articulations.

The vomer has four: On its antero-lateral part it has a small tubercle which articulates with the maxilla; dorsally with the ethmoid and the prefrontals; posteriorly with the parasphenoid.

THE SUBORBITAL RING. (Plate XXV, fig. 1.)

The suborbital ring is made up of seven bones. The largest is at the anterior end of the ring, and they gradate down to the fifth, which is the smallest. They articulate with the frontal and prefrontal. The frontal extends out laterally, and a double notch is formed; by this the anterior suborbital articulates with it. The two suborbitals at the ends are the largest of the ring.

Suborbital 1.

This is roughly rectangular in shape, the dorsal edge being shorter than the ventral, as the two dorsal corners are cut off. A section of the bone is triangular at the posterior end, the anterior end being thin. The lateral face is convex on the long axis, and is marked by five foramina, the three larger connecting with each other by a canal. All of the suborbitals have at least two foramina, and they are all connected and make a canal through the whole ring. The upper face of the first is indented by a notch which fits over a double notch on the prefrontal, giving the ring a good articulation at the anterior end. The articulation of suborbital 1 and suborbital 2 is triangular. Suborbital 1 is cut off posteriorly at the expense of the dorsal face, making a triangular face for the articulation with suborbital 2.

Suborbitals 2, 3, 4.

These are very much alike in shape. The ventral edge of each is about twice as long as the dorsal, making a notch in the posterior end of each, into which the next suborbital fits. All three are triangular in section, with the base of the triangle ventral. All have a foramen at each end, posterior and anterior, and all are connected by a canal. Each of the suborbitals projects posteriorly under the succeeding bone.

Suborbital 5.

The fifth is differently shaped and does not enter into the ventral face of the ring. The sixth suborbital sends a projection anteriorly to meet the posterior projection of suborbital 4, so that suborbital 5 is above.

Suborbital 6.

The sixth meets the projection of the fourth on the ventral border of the ring. It is about twice as long as wide, the posterior end being irregular, making a dentate suture with the seventh.

Suborbital 7.

The seventh, and the last of the ring, is wider at the posterior end than at the anterior. It articulates with the frontal, which has a deep depression for this articulation. There is a canal on the frontal, continuous with the canal extending through the ring. The whole ring is covered with small tracings, which do not show in the drawing.

SUSPENSORIUM OF THE MANDIBLE. (See plate XXV.)

The suspensorium of the mandible includes three bones—quadrate, symplectic and hyomandibular.

HYOMANDIBULAR. (Plate XXV, fig. 1; plate XXXIV, figs. 55, 56.)

The hyomandibular is a flat bone, rectangular dorsally, with a long projection extending ventrally. The outer face is convex with a slight concavity in the center of the lower two-thirds of the bone. The inner face parallels the outer and is consequently concave. The dorsal edge is almost straight and articulates with the pterotic. The dorsal anterior corner is drawn out into a slight knob, which fits into a cavity in the ventral posterior part of the sphenotic.

The anterior edge is slightly concave in outline and articulates with the metapterygoid. The ventral edge is extended ventrally, a narrow strip of bone, rounded on the posterior edge and thin on the anterior. The ventral edge is cut off squarely and articulates with the symplectic.

The posterior edge is indented by a deep notch, into which the preopercular fits. The dorsal edge of this notch is drawn out posteriorly into a rounded process which articulates with the opercular.

The inner face is concave and marked with striations. In the dorsal part it has two large foramina and several small ones. The most ventral foramen extends through the bone and comes out on the exterior face in the ridge which extends down the bone.

The outer face shows more irregularities than the inner. A ridge starts on the dorsal posterior edge and extends in a diagonal direction down the projection. The anterior part of this ridge is sharp and at right angles to the rest of the bone, really making a narrow face. Another slight elevation starts at the dorsal anterior corner, at the head of the hyomandibular, and extending diagonally, meets the long ridge. From the articulation with the opercular there is a ridge extending anteriorly and dorsally. The only foramen in the bone is placed a little ventrally to the median line. It is on the ridge and has a long fossa extending up to it. It goes through the bone and comes out on the inner face.

Articulations.

The hyomandibular articulates dorsally with the pterotic, prootic and sphenotic. Anteriorly, with the metapterygoid,

the posterior edge of which has a slight groove into which the anterior edge of the hyomandibular fits. Ventrally it articulates with the symplectic. Both bones are concave on the articulating surface, so they are probably connected by a cartilage. Posteriorly it articulates with the preopercular, which fits into the notch on its posterior edge. It also articulates with the opercular on this edge by a rounded projection.

METAPTERYGOID. (Plate XXV, Metap.; plate XXXI, figs. 27, 28.)

The metapterygoid is a thin bone, rather triangular in shape, with the edges a little convex. The base of the triangle corresponds to the base of the bone. The outer face is striated, very thin anteriorly and thickened posteriorly. The posterior edge is grooved to receive the anterior edge of the hyomandibular. This face is concave and is slightly twisted to the posterior at the antero-ventral point.

The inner face is smooth, is convex dorso-ventrally, and slightly concave along the lower part of the bone.

Articulations.

It articulates posteriorly with the hyomandibular. The hyomandibular fits into a groove in the posterior edge of the bone. At the lower part it has a slight articulation with the dorso-anterior edge of the symplectic. The anterior edge is free, except at the ventral part, where it is rounded, and articulates with the mesopterygoid by overlapping its outer face. Ventrally it articulates with the anterior dorsal edge of the quadrate. The anterior part of the articulation is merely the thin edges meeting, but at the posterior part of the articulation both bones thicken and are concave on the articulating surface.

SYMPLECTIC. (Plate XXV, Sym.; plate XXXV, fig. 57.)

This is a wedge-shaped, triangular bone, with the base of the triangle placed dorsally. The faces are fairly smooth and are not in any way marked. The anterior edge is beveled at the expense of the outer face and is slightly grooved. The posterior edge is irregular. With the bones in position only about two-thirds of the symplectic can be seen from the lateral view of the skull, the other third being sheathed in the quadrate. On the inner side all of the bone can be seen. It fits in a wedge-shaped notch on the dorsal posterior edge of the quadrate and is firmly fixed there, about two-thirds of the bone being in this sheath.

Articulations.

It articulates dorsally with the hyomandibular. The lower two-thirds is sheathed in the quadrate and the dorsal one-third articulates with metapterygoid. Posteriorly it articulates with the quadrate on the lower third of the posterior edge, the other one-third being free.

QUADRATE. (Plate XXV, Quad.; plate XXXV, figs. 57, 58.)

The quadrate is a peculiarly shaped bone, occupying the angle of the suspensorium. The posterior part of the bone is heavy and the anterior part is thin and fan-shaped. There is a notch on the inner side where the symplectic is sheathed.

The outer face is rod-like at the posterior part, and the anterior part is thin. Anterior to the rod-like posterior end the face is pushed inwardly so that the fan-shaped portion is farther in than the heavy part at the posterior. The face is marked with small ridges and numerous foramina. All converge at the posterior ventral angle. The inner face of the bone is striated and has numerous ridges like the outer face. On the anterior edge there is a depression, dropped below the rest of the face and forming an articulation. This depression occupies about one-third of the face. It narrows down ventrally and furnishes a good articulation for the pterygoid. The ventral posterior angle is pushed in, forming an articulation with the mandible.

The posterior part of the quadrate is very heavy and solid. It is smaller dorsally, swelling out a little below the median line, then narrowing again, forming a constriction above the lower ventral part, which is the heaviest part of the bone. The posterior face of this part is deeply grooved, the groove fitting over the preopercular. The deep notch between the rod and the fan-shaped part is cut out at the expense of the inner face, only half of the notch showing from the outer view of the quadrate.

The articulation for the mandible is in two parts, divided by a constriction. This articulating surface points slightly anteriorly. The larger part of the articulation is at the ventral part of the rod. The lower part is expanded and makes a large convex surface.

Articulations.

The quadrate has six articulations: Anteriorly with the pterygoid by overlapping it, a notch being cut out of the quadrate to receive it; with the mesopterygoid at the anterior dorsal angle, the edges resting against each other; superiorly with the metapterygoid, the edges meeting; with the symplectic by sheathing it; posteriorly with the preopercular, and ventrally with the mandible.

MESOPTERYGOID. (Plate XXV, fig. 1; plate XXXI, figs. 25, 26.)

This is a thin bone between the metapterygoid and pterygoid. It is expanded at the posterior dorsal part, forming a thin posterior end. Its ventral edge is almost a straight line, but a little convex. The anterior end is quite narrow. The expanded part is quite thin on the edge, and rounds over from the posterior to near the center, where it drops down abruptly, making the narrow anterior part.

The lateral face is concave from posterior to anterior, the posterior part is folded and waved. The inner face is convex, the anterior dorsal edge twisted so that it points out laterally, the ventral edge pointing inward.

Articulations.

The mesopterygoid has three articulations, its ventral edge fitting into a groove on the dorsal edge of the pterygoid, posteriorly with the metapterygoid. It has a slight articulation with the quadrate.

PTERYGOID. (Plate XXV Pt.; plate XXXV, figs. 57, 58.)

The pterygoid is a stout bar uniting the quadrate and palatine. The anterior end is heavy and triangular in section, the base of the triangle dorsal, its inner edge inclined a little ventrally. Posteriorly it bends ventrally and laterally, and expands to about twice the depth. The anterior end is narrowed down to a rough point which articulates with the prefrontal. The pterygoid is cut out on the antero-ventral part and also on the lateral part, making an articulation for the palatine. On the dorsal edge the inner part has a deep, angular groove, into which the mesopterygoid is placed, it being grooved also.

The posterior end of the pterygoid is rather thin and is drawn downward and a little outward. Immediately posterior to the place where it turns down a thin plate of bone extends

dorsally, so that the posterior end is slightly forficate. The outer part of this downwardly inclined part is depressed sharply along the upper part of the face, where it fits against the inner face of the quadrate, the edges of this depression being serrated.

Articulations.

It has five: Anteriorly with the palatine and the prefrontal; dorsally with the mesopterygoid; posteriorly with the quadrate. It touches the metapterygoid.

PALATINE. (Plate XXV, Pal.; plate XXXV, fig. 58.)

The palatine is a very heavy, thick bone, and bears teeth on the ventral edge. The bone may be called triangular in shape, with the base dorsal. A long prolongation extends forward and outward from the dorsal outer angle of the bone.

The outer face is slightly concave both ways. The upper dorsal edge is cut down obliquely at the posterior part and is drawn out posteriorly from the ventral side, the posterior part being cut out behind the teeth, and extends dorsally at right angles for a short distance and then runs posteriorly. (Plate XXXV, fig. 57, P.) In front of the anterior end of the oblique dorsal edge the edge dips down and makes a notch, and in front of this the anterior projection starts and extends forward. This prolongation narrows down at the anterior end and becomes quite small.

The inner face is slightly concave both ways. The oblique part is serrated, and is drawn out laterally. On the anterior part of the prolongation at the base there is a small protuberance, which furnishes the articulating surface with frontal.

The dorsal face of the palatine is concave at the posterior half and is inclined obliquely posteriorly. The edges are extended dorsally, making a groove for the pterygoid. Anterior to this articulating surface the bone drops ventrally and then rises, making a notch. The bottom of this is marked by several foramina. Anterior to this the prolongation starts forward.

The ventral face is tooth-bearing and has from five to seven teeth. The teeth are in a single row anteriorly, and posteriorly they may be paired. These are good-sized teeth, and work against those on the mandible as they are close to the vomer, lying on each side of it. All of the palatine teeth have rounded surfaces.

Articulations.

The palatine has two. On the dorsal edge it articulates with the pterygoid, and the anterior part of the inner face with the frontal. The anterior prolongation fits in between the first suborbital and the vomer, but touches neither.

MAXILLA. (Plate XXV, Max.; plate XXXV, figs. 59, 60.)

The maxilla is a long, slender bone, bearing no teeth and having nothing to do with mastication. Its anterior end is elliptical and the posterior end is very thin. The outer face is convex posteriorly and slightly concave at the anterior end. At about four-fifths of the distance to the posterior end the bone is constricted, and back of this it becomes very thin. At the anterior end the bone is drawn down ventrally and forms a head or condyle, which articulates with the vomer.

Articulations.

The maxilla has three articulations. The articulation on the vomer is near the anterior end and the two maxillæ touch each other at the anterior end. The articulation with the premaxilla is along the ventral edge. The ventral part of the condyle fits into a small depression on the inner side of the premaxilla.

PREMAXILLA. (Plate XXV, Premax.; plate XXVIII, figs. 5, 6.)

The premaxilla has a good supply of teeth, most of them being canine-shaped. The number is different, but averages 8 or 9. The first four or five are large and the rest are small and rounded. The anterior tooth is usually single; posterior to this the large ones form a double row, and the remaining small ones a single row.

Outer Face. (Plate XXVIII, fig. 5.)

The premaxilla is shaped in a peculiar manner. The anterior part of the bone is heavy and the long axis is placed dorso-ventrally. At the base of the posterior edge there is a projection which points posteriorly. It narrows down back of the teeth and becomes a spine. This projection is at right angles to the rest of the bone. The outer face is convex and is marked by striations. At the base of the two anterior teeth there are two foramina. The dorsal edge is rounded at the expense of the posterior edge.

The inner face of the premaxilla is rather irregular. The anterior part of the face is smooth and is the symphyseal surface. Posterior to this it is very rough. There is a groove

which extends from top to bottom, cutting off a part of the articulating surface. The bone is depressed dorsally to the teeth and also on each side of the posterior projection.

Articulations.

It articulates with the other premaxilla on the median line; with the ethmoid, its dorsal posterior edge fitting into a concavity on the anterior face of the ethmoid; posteriorly with the maxilla, the condyle of the maxilla fitting into a facet on the premaxilla.

MANDIBLE. (Plate XXV, Man.; plate XXXVI, figs. 61, 62, 63.)

The mandibles, in this family, are well built, and are different from most fish jaws. The two rami are joined by a weak suture, and are held by tissue. The two rami are at an angle of about 45 degrees to each other. The symphyseal surface is rectangular in shape, slightly narrowed at the ventral border. The ventral edge of the mandible is the base of the dentary, and is straight, except at a point near the chin, where it curves slightly ventrally. The anterior edge is gently concave, and also the dorsal border. The dorsal border is the tooth-bearing surface. It is raised up to make a place for the teeth. Posterior to the teeth the mandible is elevated dorsally and ends in the coronoid process. The posterior edge is cut off obliquely at the expense of the dorsal edge. At the lower part is found the articulation for the quadrate.

The outer face is rounded. The greatest width of the ramus is at about the middle of the bone. At the dorsal edge there is a depression ventral to the teeth.

The inner face of the mandible is made up of the inner faces of dentary and articulare. There is a large cavity posterior to the teeth, extending anteriorly. At about the middle the upper part of the face is cut off, and ventrally a long ramus extends posteriorly along the ventral edge of the articulare.

There are three bones in the mandible to be described. The splenial is reduced and is seen merely as a splint, and cannot be described separately. The other three bones are the dentary, articulare and angulare.

DENTARY. (Plate XXV, Den.; plate XXXVI, figs. 61, 62, 63.)

The dentary is the largest bone in the mandible, and in describing it one almost defines the whole mandible. The anterior

edge of the dentary is oblique and the lower edge is cut off by this. The posterior of the dentary is forficate and sheaths the anterior projection of the articulare. The greatest thickness of the dentary is along the median line. Ventral to this it is inclined rapidly inward. Dorsal to the median line it is rapidly depressed and the outer line of the teeth falls inside of the base line of the inner face. This upper depression is posterior to the canine teeth, as they are located where the mandible is rather thick. The outer face is marked by several foramina. Just below the median line there are four. In the depression below the teeth there are two of noticeable size at the anterior part. There is also a foramen in the posterior end of the lower fork of the dentary. The whole face is striated and marked with small holes. At the base of the anterior teeth there is a pit. The ventral line is almost straight, but at the anterior end it is curved upward, making a protuberance for the chin.

The inner face is rather plain and is striated. This face is one plane for the most part. At the middle of the upper part the face is drawn inward so that the teeth are inclined inward. The front is beveled and forms the symphyseal surface. This is formed at the expense of the inner face. Back of the teeth the face is cut out, making the large hollow in the mandible. There is a cavity extending anteriorly into the bone.

The dentary has but two articulations. It meets the other dentary in front, and at the posterior articulates with the articulare. The dentary sheaths the articulare.

ARTICULARE. (Plate XXXVI, figs. 61, 62, 63.)

The articulare is a triangular bone, thick posteriorly and very thin anteriorly, making it wedge-shaped, the anterior point being in the fork of the dentary. The outer face is rounded and is striated. The ventral face is wedge-shaped and rests on the dentary. At the posterior it drops down and makes an articulating surface for the angulare.

The dorsal part is extended upwards in a projection and helps to make the coronoid process. At the posterior end the bone is thick and has articulating surfaces for the quadrate and angulare. Immediately in front of the articulations with the quadrate the bone becomes thin. The ventral face of the articulare, although wide, may be called a shelf, as the upper edge is thin in a horizontal plane.

ANGULARE. (Plate XXXVI, figs. 61, 62.)

The angulare is a small bone placed at the ventral, posterior angle of the mandible. Its anterior end is small, and the posterior part is enlarged and rounded. The bone fits in a depression in the articulare.

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DESCRIPTION OF PLATES.

All drawings natural size, unless otherwise indicated. Magnifications indicated on the plates represent the original enlargements; those in the explanations the size as reproduced.